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Evaluation of motorcycle antilock braking systems, alone and in conjunction with combined control braking systems – an update

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Summary

This is the largest Highway Loss Data Institute (HLDI) study to date on motorcycle antilock braking systems (ABS), utilizing more than 2 million years of collision exposure and 59 different motorcycle series. This report examines the effectiveness of ABS and the combination of ABS and combined control braking systems (CCBS) on insurance losses under collision, bodily injury liability and medical payment coverages. For the first time, the effectiveness of ABS by motorcycle class is examined.

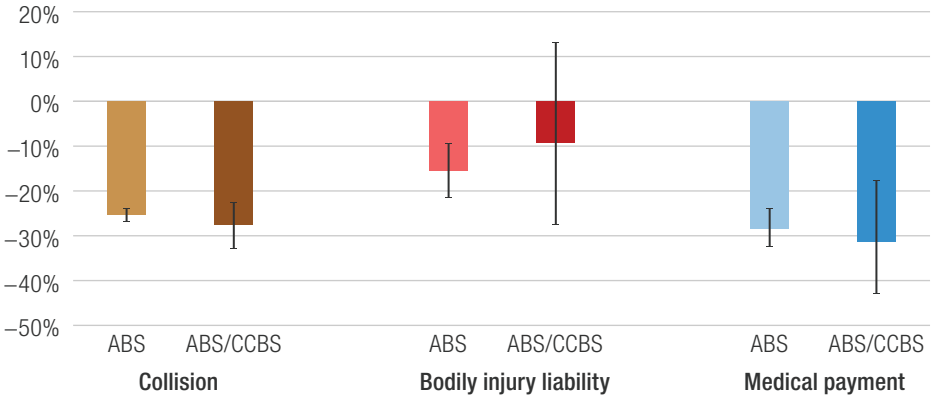
For all of the motorcycles in this study, ABS was available as optional equipment, and the presence of ABS systems could be determined from the VIN. CCBS was either standard or not available. Losses for motorcycles with and without ABS and with and without ABS/CCBS were compared. The method used in this analysis could not estimate the effect of CCBS alone.

As shown in the figure below, ABS was associated with claim frequency reductions under collision, bodily injury liability and medical payment of 25%, 16% and 29% respectively.

ABS combined with CCBS was also associated with claim frequency reductions of 28%, 9%, and 32% under collision, bodily injury liability and medical payment coverages.

Results by motorcycle class indicate that sport/unclad sport and sport touring motorcycles experienced the largest collision claim frequency reductions when equipped with ABS while supersport motorcycles experienced the smallest reduction.

Estimated change in claim frequency by ABS and CCBS availability and coverage type



Introduction

With only two wheels, motorcycles skid and tip onto their sides more easily than cars. They are also harder for other drivers to see and frequently pack high horsepower and accelerate rapidly. Because there is no enclosure to protect them, motorcycle riders are more likely than automobile drivers to be injured or killed in the event of a crash. In 2023, more than 6,000 motorcyclists died as the result of such collisions. Safety measures that make motorcycle crashes less likely, including antilock braking systems (ABS), should significantly reduce the risk of rider injury or death.

Unlike four-wheeled vehicles, motorcycles do not stay upright on their own. At low speeds, riders maintain stability by holding the handlebar; at higher speeds, stability is primarily due to the wheels' gyroscopic effects. Motorcycles become unstable if a wheel stops rotating, even briefly; if the front wheel locks, a fall is almost inevitable, especially when cornering. By utilizing independent sensors for each wheel, ABS enables controlled urgent stops. If a wheel lock is detected, the system releases the brake to allow the tire to regain traction on the ground and then reapplies the brake, modulating pressure for optimal braking (Highway Loss Data Institute [HLDI], 2008). ABS also improves steering stability and provides better control, especially on wet surfaces.

Increasingly, motorcycles are equipped with ABS systems that integrate the control of the front and rear brakes. In this study, these systems will be referred to as combined control braking systems (CCBS). These systems can apply force from both brakes even if only one brake control is actuated by the rider. There are a variety of implementations. One implementation can be found on the 2013 Yamaha FJR1300. The FJR1300 has eight brake pistons on the front wheel and two on the rear. When a rider actuates the front brake control, six of the front brake pistons activate, while none of the rear activate. When a rider actuates the rear brake control, all of the rear brake pistons activate and two of the front brake pistons activate. All eight front brake pistons are activated only when the rider actuates both brake controls. Honda utilizes a different type of CCBS that electronically distributes brake force over both wheels with either control. The system electronically measures rider input on the brake controls and applies both brakes or only the front or rear.

Research conducted by the Insurance Institute for Highway Safety found that fatal crash rates are 22% lower for motorcycles with optional ABS than they are for the same motorcycles without ABS. The effectiveness of ABS varies among motorcycle classes. Cruiser and standard motorcycles have the lowest mortality ratios, while supersport motorcycles have the highest (Teoh, 2022).

Previous HLDI reports found significant collision claim frequency reductions of more than 20% associated with motorcycles equipped with ABS and slightly larger reductions for motorcycles with both ABS and CCBS (HLDI, 2016). Since HLDI's last study, the availability of ABS has increased.

The purpose of this study is to provide an updated estimate on the effects of ABS and ABS with CCBS on insurance losses under collision, bodily injury liability and medical payment coverages. For all of the motorcycles in this study, ABS was available as optional equipment, and the presence of ABS systems could be determined from the Vehicle Identification Number (VIN). CCBS was either standard or not available.

Method

Insurance data

Motorcycle insurance covers damage to vehicles and property as well as injuries to people resulting from crashes. Different insurance coverages pay for physical damage versus injuries. Also, different coverages may apply depending on who is at fault. In the present study, collision coverage, medical payment and bodily injury liability were examined. Collision coverage insures against physical damage to a motorcycle sustained in a crash when the rider is at fault. Medical payment coverage (MedPay) covers injuries to insured riders. For motorcycles, bodily injury liability (BI) coverage insures against injuries that at-fault operators cause to other people, including their own passengers.

Rated drivers (riders)

For insurance purposes, a rated driver is assigned to each motorcycle on a policy. HLDI collects various information about rated drivers. For the present study, data were stratified by rated driver age group (<25, 25-39, 40-64, 65+, or unknown), rated driver gender (male, female, or unknown), and rated driver marital status (married, single, or unknown). Additionally, risk (nonstandard or standard), deductible range for collision coverage only (0-100, 101-250, 251-500, or 501+), and garaging state were included.

Motorcycles

For motorcycles to be included in the study, their VINs had to have an ABS indicator. Only motorcycles with optional ABS and with loss data for both ABS and non-ABS versions were included. Only pairs with at least 1 claim for both the study and comparison motorcycles were included. A total of 69 pairs of motorcycles were included in the study.

The 69 pairs were separated into two groups — a group to evaluate the effect of ABS and a group to evaluate the effect of ABS in conjunction with CCBS. The ABS group included 59 pairs, and the ABS/CCBS group included 10 pairs. In the ABS study group, it should be noted that some of the pairs were also equipped with CCBS, and for those pairs, both the ABS and non-ABS motorcycles had CCBS. Likewise, for pairs that did not have CCBS, neither the ABS nor non-ABS motorcycles had CCBS. In the ABS/CCBS group, the ABS equipped motorcycles had CCBS but the non-ABS motorcycles did not. **Table 1** shows the collision exposure distribution for the study and comparison groups.

Table 1: Collision exposure percent by ABS and CCBS availability

ABS study population		
	With CCBS	Without CCBS
With ABS study group	13%	17%
Without ABS comparison group	36%	34%
ABS with CCBS study population		
	With CCBS	Without CCBS
With ABS study group	15%	0%
Without ABS comparison group	0%	85%

Appendix Table A1 lists the motorcycle make and series and their exposure for all three coverage types (collision, bodily injury liability, medical payment) by ABS and CCBS availability.

Table 2 shows the exposure and claims for all three coverage types by the availability of ABS and ABS with CCBS. Both exposure and claims are 3 to 5 times as large as in the similar April 2013 study. Exposure and claims under bodily injury liability and medical payment coverages are now sufficient to study the effect of ABS with CCBS on those coverages.

Table 2: Exposure and claims by coverage type, comparing the last study and current study

	April 2013 study			Current study			Percentage change	
	Exposure	Claims	Exposure percent	Exposure	Claims	Exposure percent	Exposure	Claims
Collision - ABS								
With ABS	91,823	1,587	24%	711,034	13,309	30%	526%	563%
Without ABS	287,836	5,899	76%	1,666,330	36,303	70%		
Total	**379,660**	**7,486**		**2,377,364**	**49,612**			
Collision - ABS with CCBS								
With ABS/CCBS	12,675	393	26%	45,550	976	15%	527%	326%
Without ABS/CCBS	35,202	1,983	74%	254,677	9,145	85%		
Total	**47,878**	**2,376**		**300,228**	**10,121**			
BI-ABS								
With ABS	84,202	121	24%	835,123	1,234	29%	723%	711%
Without ABS	266,507	459	76%	2,051,825	3,472	71%		
Total	**350,709**	**580**		**2,886,948**	**4,706**			
BI - ABS with CCBS								
With ABS/CCBS				56,178	100	14%		
Without ABS/CCBS				333,595	795	86%		
Total				**389,773**	**895**			
MedPay - ABS								
With ABS	23,080	238	23%	206,779	2,127	28%	629%	584%
Without ABS	79,029	1,077	77%	537,279	6,865	72%		
Total	**102,109**	**1,315**		**744,057**	**8,992**			
MedPay - ABS with CCBS								
With ABS/CCBS				13,056	154	15%		
Without ABS/CCBS				73,930	1,497	85%		
Total				**86,987**	**1,651**			

Statistical analysis

Regression analysis was used to quantify the effect of ABS and ABS with CCBS on motorcycle insurance losses. Covariates included motorcycle make and series; calendar year; vehicle age; garaging state; vehicle density; rated driver age group; rated driver gender; rated driver marital status; deductible range for collision coverage; and rated driver risk.

Claim frequency was modeled using a Poisson distribution, and claim severity was modeled using a Gamma distribution. Both variables were modeled using a logarithmic link function. Estimates for overall losses were derived from the claim frequency and claim severity models. Estimates for claim frequency are presented for collision, BI, and MedPay coverage types. BI and MedPay claim frequencies are for all claims, including those that have been paid and those for which money has been set aside for possible payment in the future, known as claims with reserves.

The estimated effect of ABS or ABS combined with CCBS is presented as a percent change. The percent change was calculated by subtracting 1 from the exponent of the parameter estimate for the crash avoidance technology indicator variable and multiplying the resultant by 100. A percent change less than 0 indicated that the crash avoidance technology was associated with a reduction in the outcome measure, and a value above 0 indicated the technology was associated with an increase in the outcome measure. The percent change can be considered statistically significant when the 95 percent confidence interval does not include 0.

Results

Observed losses

Figure 1 shows the observed claim frequency for the two study groups and all three coverage types. Claim frequencies for motorcycles with ABS alone were 13% to 19% lower than for motorcycles without ABS. Motorcycles with ABS and CCBS also showed lower claim frequencies than those without, with claim frequencies benefits from 25% for BI to 42% for medical payment.

Figure 1: Observed claim frequency by ABS and CCBS availability

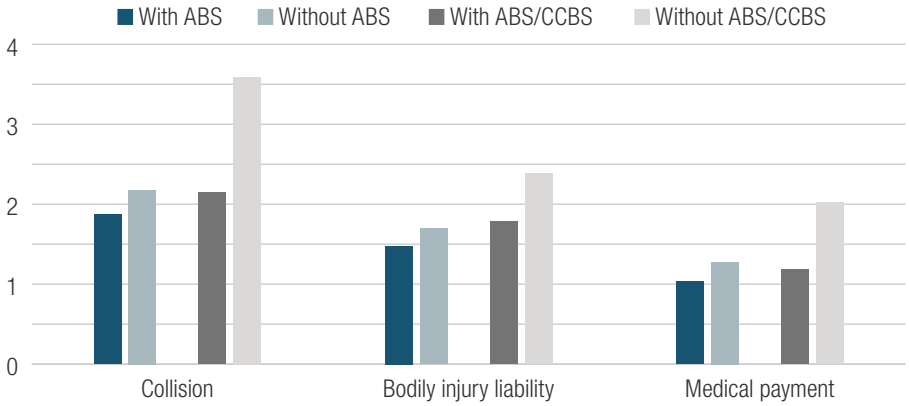


Figure 2 shows the observed claim severity for the two study groups and all three coverage types. Motorcycles equipped with ABS show slightly higher claim severities than those not equipped with ABS. Motorcycles with ABS and CCBS also showed higher claim severities than those without, and the difference was largest under bodily injury liability at more than an $8,000.

Figure 2: Observed claim severity by ABS and CCBS availability

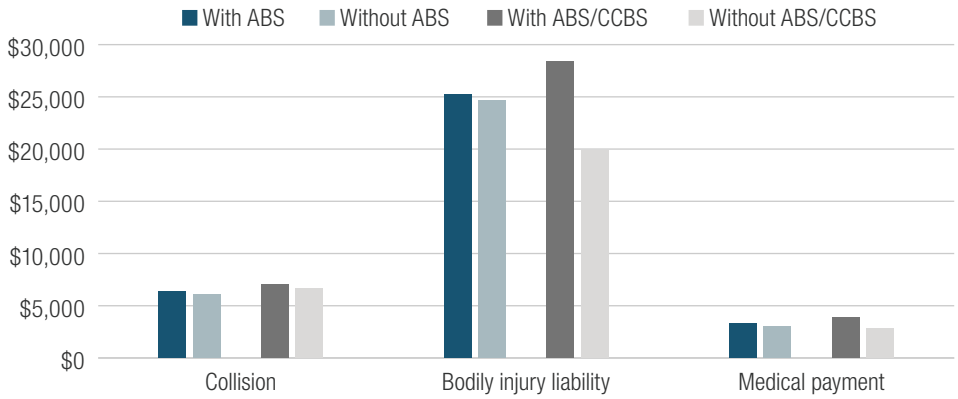


Figure 3 shows the collision exposure weighted base price. Motorcycles with ABS cost about $300 more than motorcycles without ABS, and motorcycles with ABS and CCBS cost about $1,100 more than motorcycles without those technologies.

Figure 3: Collision exposure-weighted base price by ABS and CCBS availability

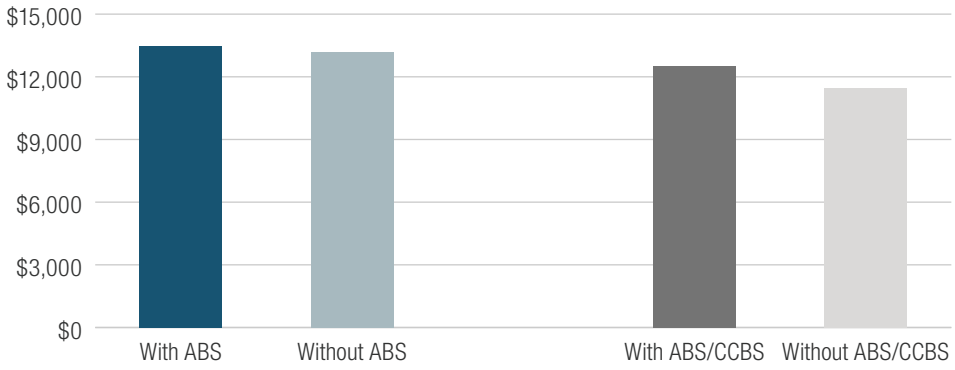
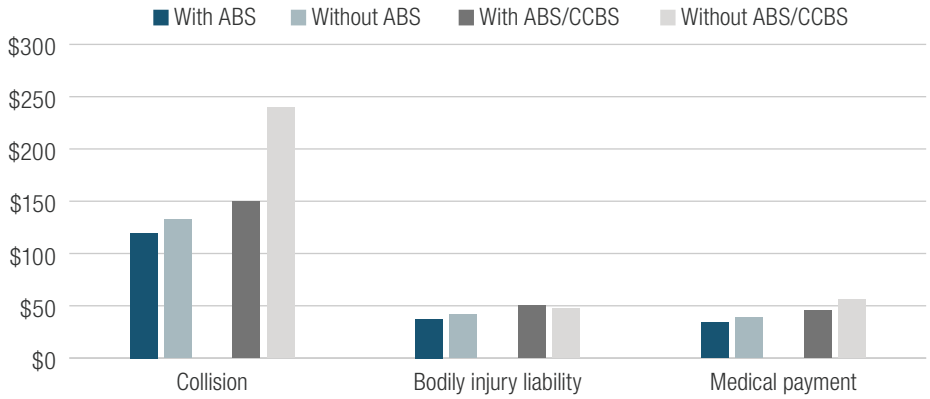


Figure 4 shows the observed overall losses for the two study groups and all three coverage types. With the exception of bodily injury liability, motorcycles with ABS and motorcycles with ABS and CCBS had lower overall losses than their respective comparison groups. A nearly $100 difference in collision overall losses was observed for motorcycles with and without ABS/CCBS.

Figure 4: Observed overall losses by ABS and CCBS availability



Estimated differences in insurance losses

Figure 5 shows the estimated effects of ABS and ABS with CCBS on claim frequency.

Under collision coverage, claim frequency was 25% lower for motorcycles with ABS and 28% lower for motorcycles with ABS and CCBS compared with their unequipped counterparts.

Under bodily injury liability coverage, claim frequency was 16% lower for motorcycles with ABS and 9% lower for motorcycles with ABS combined with CCBS compared with unequipped motorcycles. However, only the reduction associated with ABS alone was statistically significant.

Under medical payment, a 29% claim frequency reduction was associated with ABS, and an even larger 32% reduction was found for ABS combined with CCBS.

Figure 5: Estimated change in claim frequency by ABS and CCBS availability and coverage type

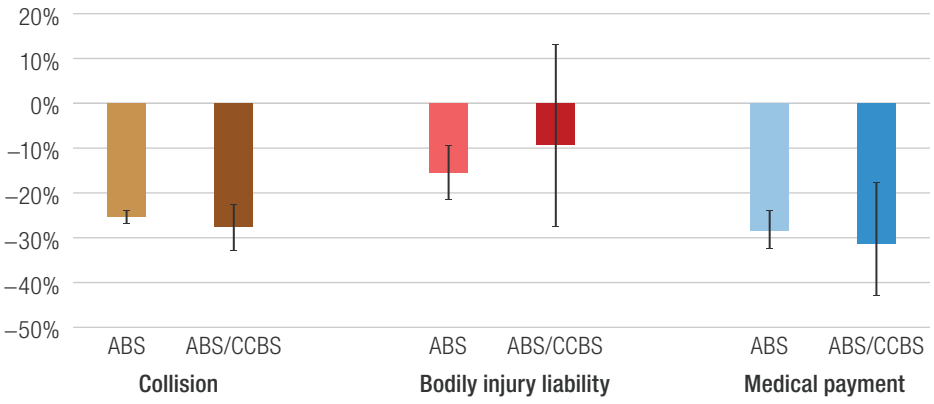


Figure 6 shows the estimated effects of ABS and ABS with CCBS on claim severity. Motorcycles with ABS and motorcycles with ABS and CCBS show higher severity across all three coverage types, compared with their respective comparison groups. However, none of the effects were statistically significant.

Figure 6: Estimated change in claim severity by ABS and CCBS availability and coverage type

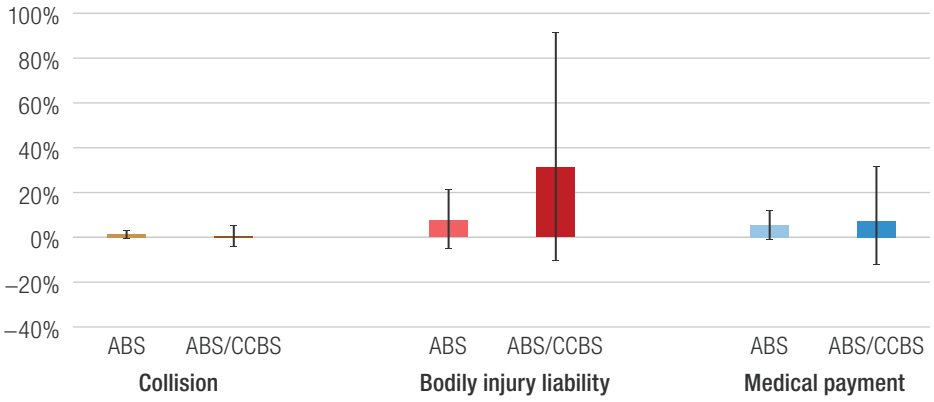


Figure 7 shows the estimated effects of ABS and ABS with CCBS on overall losses. For collision and medical payment, motorcycles with ABS and motorcycles with ABS and CCBS both reduced overall losses by 24% to 27%. The findings for bodily injury liability were not statistically significant.

Figure 7: Estimated change in overall losses by ABS and CCBS availability and coverage type

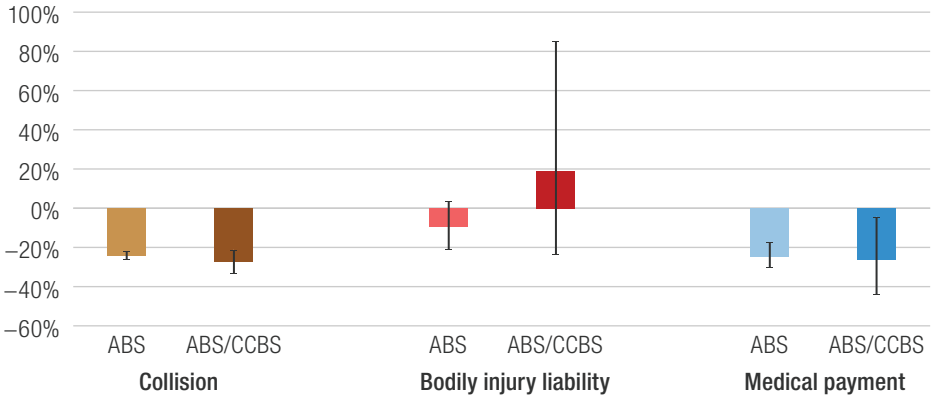
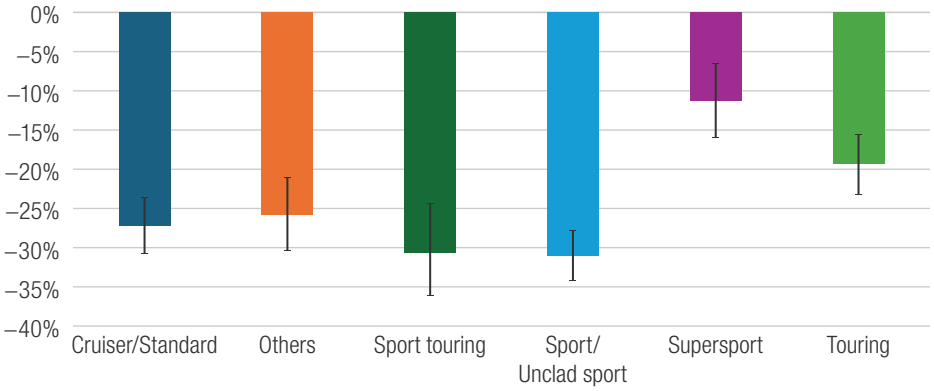


Figure 8 shows the estimated effect of ABS on collision claim frequency by motorcycle class. Sport/unclad sport, and sport touring motorcycles showed the largest reductions (31%), followed by cruiser/standard motorcycles at 27%. ABS on other motorcycles (chopper, scooter, dual purpose) reduced collision claim frequency by 26%. ABS on supersport motorcycles reduced collision claim frequency by only 11%.

Figure 8: Estimated change in collision claim frequency for ABS by motorcycle class



Discussion

Prior HLDI and IIHS studies have shown that ABS on motorcycles is correlated with reductions in insurance losses and fatalities. In this updated look, ABS on motorcycles was estimated to result in statistically significant reductions in claim frequencies for collision (25%), bodily injury liability (16%) and medical payment (29%) coverages. ABS combined with CCBS was estimated to result in statistically significant reductions in claim frequencies under collision (28%) and medical payment (32%) coverages.

Although the observed results show slightly higher claim severities for motorcycles with ABS and motorcycles with both ABS and CCBS, no statistically significant changes in claim severities were found.

This HLDI study is the first to look at the effectiveness of ABS on insurance losses by motorcycle class. It found reductions varied from 11% for supersport motorcycles, which often have high claim frequencies, to 31% for sport touring, sport/unclad sport motorcycles.

Although this and prior reports have shown the benefit of ABS for motorcycles, ABS is not currently required in the United States. Nevertheless, manufacturers have made the technology available on a greater portion of new motorcycles over recent years. ABS is standard on nearly two-thirds of model year 2023 motorcycles (HLDI, 2024).

References

Highway Loss Data Institute. (2016). Evaluation of motorcycle antilock braking systems — an update. *Loss Bulletin*, *33*(24).

Highway Loss Data Institute. (2024). Availability of motorcycle antilock braking systems. *Loss Bulletin*, *41*(35).

Teoh, E. R. (2022). Motorcycle antilock braking systems and fatal crash rates: updated results. *Traffic Injury Prevention*, 23(4), 203–207. https://doi.org/10.1080/15389588.2022.2047957

Appendix

Prior HLDI studies of motorcycle ABS

Publication year	HLDI *Loss Bulletin* issue
2008	Vol. 25, No. 1
2009	Special report A-81
2012	Special report A-84
2013	Vol. 30, No. 10
2014	Vol. 31, No. 11

Table A1: Distribution of exposure for antilock and combined control brake systems, collision, bodily injury liability, and medical payments coverage									
	Collision			Bodily injury liability			Medical payments		
	Exposure	Percent ABS	Percent non-ABS	Exposure	Percent ABS	Percent non-ABS	Exposure	Percent ABS	Percent non-ABS
Aprilia Scarabeo 500	2,262	63%	37%	3,198	63%	37%	755	65%	35%
Harley Davidson V-Rod	33,898	26%	74%	37,990	26%	74%	10,357	22%	78%
Honda CB1100	14,561	12%	88%	18,718	11%	89%	4,781	11%	89%
Honda CB300F	3,056	36%	64%	4,592	36%	64%	1,083	30%	70%
Honda CB500F	17,703	25%	75%	25,417	24%	76%	5,720	22%	78%
Honda CB500X	16,703	25%	75%	22,875	24%	76%	5,531	23%	77%
Honda CBR1000RR	40,593	11%	89%	59,661	10%	90%	10,155	10%	90%
Honda CBR250R	27,063	16%	84%	47,327	15%	85%	10,760	15%	85%
Honda CBR300R	16,232	26%	74%	25,127	25%	75%	5,363	23%	77%
Honda CBR500R	28,203	23%	77%	44,182	22%	78%	10,023	21%	79%
Honda CBR600RR	53,502	7%	93%	77,839	6%	94%	14,816	6%	94%
Honda CBR650F	8,979	17%	83%	12,849	17%	83%	2,873	14%	86%
Honda CRF300L	14,105	41%	59%	13,251	41%	59%	4,334	41%	59%
Honda CTX1300	9,152	56%	44%	9,960	56%	44%	2,746	58%	42%
Honda CTX700	19,069	59%	41%	22,277	58%	42%	6,416	58%	42%
Honda CTX700N	20,496	49%	51%	24,817	48%	52%	7,091	50%	50%
Honda Forza	10,418	24%	76%	12,916	23%	77%	4,000	22%	78%
Honda Fury	73,715	2%	98%	85,709	2%	98%	18,989	2%	98%
Honda Gold Wing	850,924	22%	78%	905,810	22%	78%	269,356	20%	80%
Honda Grom	66,036	15%	85%	81,257	15%	85%	19,492	15%	85%
Honda Interceptor (2002-09)	41,951	27%	73%	64,026	24%	76%	13,164	23%	77%
Honda Interceptor (2014-15)	4,916	50%	50%	5,842	49%	51%	1,399	48%	52%
Honda NC700X	29,793	25%	75%	39,938	24%	76%	10,360	22%	78%
Honda PCX150	7,107	24%	76%	8,252	22%	78%	2,390	21%	79%
Honda Rebel 300	28,220	37%	63%	31,056	36%	64%	8,041	35%	65%
Honda Rebel 500	43,270	43%	57%	46,330	41%	59%	11,599	43%	57%
Honda Reflex	36,571	14%	86%	56,039	13%	87%	17,048	13%	87%
Honda Silver Wing	42,936	18%	82%	61,567	17%	83%	18,269	17%	83%
Honda ST1300	67,223	32%	68%	85,751	31%	69%	22,091	29%	71%
Honda Stateline	16,134	8%	92%	18,319	8%	92%	4,215	7%	93%
Indian Scout	83,146	66%	34%	81,283	64%	36%	21,417	64%	36%
Indian Scout Sixty	26,456	59%	41%	25,655	57%	43%	6,786	58%	42%
Kawasaki Concours 14	46,007	55%	45%	56,889	54%	46%	14,108	53%	47%
Kawasaki KLR 650	13,127	34%	66%	11,812	30%	70%	3,305	32%	68%
Kawasaki KLX 230	5,475	35%	65%	6,123	34%	66%	1,658	30%	70%
Kawasaki Ninja 1000	7,071	40%	60%	10,383	40%	60%	2,075	42%	58%
Kawasaki Ninja 300	70,383	44%	56%	112,956	43%	57%	23,029	41%	59%
Kawasaki Ninja 650	32,197	45%	55%	46,269	44%	56%	9,182	40%	60%
Kawasaki Ninja ZX-10R	11,991	35%	65%	17,455	33%	67%	2,799	38%	62%
Kawasaki Ninja ZX-14R	11,002	52%	48%	14,435	51%	49%	2,479	51%	49%

Table A1: Distribution of exposure for antilock and combined control brake systems, collision, bodily injury liability, and medical payments coverage									
	Collision			Bodily injury liability			Medical payments		
	Exposure	Percent ABS	Percent non-ABS	Exposure	Percent ABS	Percent non-ABS	Exposure	Percent ABS	Percent non-ABS
Kawasaki Ninja ZX-6R	43,169	44%	56%	56,591	42%	58%	10,433	43%	57%
Kawasaki Versys-X 300	6,621	49%	51%	8,285	49%	51%	2,274	49%	51%
Kawasaki Vulcan 1700	30,442	38%	62%	32,916	38%	62%	10,380	35%	65%
Kawasaki Vulcan S	52,923	57%	43%	57,441	57%	43%	14,561	56%	44%
Suzuki Bandit 1250	11,993	26%	74%	18,841	26%	74%	4,051	24%	76%
Suzuki Burgman 400	3,148	99%	1%	4,002	99%	1%	1,129	99%	1%
Suzuki Burgman 650	49,493	27%	73%	68,423	26%	74%	18,356	27%	73%
Suzuki SV650	35,439	17%	83%	56,580	14%	86%	12,029	13%	87%
Suzuki V-Strom 650	32,798	18%	82%	48,844	16%	84%	11,347	17%	83%
Triumph Speed Triple	4,662	44%	56%	5,783	44%	56%	1,288	40%	60%
Triumph Sprint ST	11,985	51%	49%	15,502	50%	50%	4,018	50%	50%
Triumph Thunderbird	10,579	53%	47%	12,020	52%	48%	3,539	53%	47%
Triumph Tiger	12,343	46%	54%	15,840	45%	55%	3,833	46%	54%
Triumph Tiger 800	12,156	89%	11%	14,970	89%	11%	4,032	90%	10%
Victory Cross Country	27,973	71%	29%	28,722	71%	29%	8,855	71%	29%
Victory Vision	10,944	26%	74%	11,690	25%	75%	3,666	21%	79%
Yamaha FJR1300	39,720	51%	49%	53,491	50%	50%	13,239	50%	50%
Yamaha FZ-07	8,544	40%	60%	11,968	39%	61%	2,476	38%	62%
Yamaha YZF-R3	20,763	65%	35%	28,841	63%	37%	4,478	56%	44%
Total	**2,377,364**	**30%**	**70%**	**2,886,948**	**29%**	**71%**	**744,057**	**28%**	**72%**
	Exposure	Percent ABS/CCBS	Percent non-ABS/ CCBS	Exposure	Percent ABS/CCBS	Percent non-ABS/ CCBS	Exposure	Percent ABS/CCBS	Percent non-ABS/ CCBS
Honda CB1100	14,561	12%	88%	18,718	11%	89%	4,781	11%	89%
Honda CB500F	17,703	25%	75%	25,417	24%	76%	5,720	22%	78%
Honda CB500X	16,703	25%	75%	22,875	24%	76%	5,531	23%	77%
Honda CBR1000RR	40,593	11%	89%	59,661	10%	90%	10,155	10%	90%
Honda CBR600RR	53,502	7%	93%	77,839	6%	94%	14,816	6%	94%
Honda Fury	73,715	2%	98%	85,709	2%	98%	18,989	2%	98%
Honda NC700X	29,793	25%	75%	39,938	24%	76%	10,360	22%	78%
Honda Stateline	16,134	8%	92%	18,319	8%	92%	4,215	7%	93%
Kawasaki Concours 14	7,080	75%	25%	8,381	75%	25%	2,038	73%	27%
Kawasaki Vulcan 1700	30,442	38%	62%	32,916	38%	62%	10,380	35%	65%
Total	**300,228**	**15%**	**85%**	**389,773**	**14%**	**86%**	**86,987**	**15%**	**85%**

Table A2: Illustrative regression results — motorcycle collision ABS									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	*p*-value
Intercept		1	-9.271		0.0334	-9.3365	-9.2055	77031.70	<0.0001
ABS	Equipped	1	-0.2914	-25.3%	0.0111	-0.3132	-0.2697	689.19	<0.0001
	Not equipped	0	0	0	0	0	0		
Make and series	Aprilia Scarabeo 500	1	0.4806	61.7%	0.1355	0.2151	0.7461	12.59	0.0004
	Harley Davidson V-Rod	1	0.2428	27.5%	0.0390	0.1663	0.3193	38.72	<0.0001
	Honda CB1100	1	-0.1547	-14.3%	0.0662	-0.2843	-0.0250	5.46	0.0194
	Honda CB300F	1	-0.5121	-40.1%	0.1344	-0.7756	-0.2486	14.51	0.0001
	Honda CB500F	1	-0.0550	-5.4%	0.0494	-0.1517	0.0418	1.24	0.2656
	Honda CB500X	1	-0.5024	-39.5%	0.0684	-0.6364	-0.3684	53.98	<0.0001
	Honda CBR1000RR	1	0.9271	152.7%	0.0264	0.8754	0.9788	1234.71	<0.0001
	Honda CBR250R	1	-0.2989	-25.8%	0.0449	-0.3869	-0.2110	44.36	<0.0001
	Honda CBR300R	1	-0.0465	-4.5%	0.0489	-0.1424	0.0495	0.9	0.3425
	Honda CBR500R	1	0.2591	29.6%	0.0358	0.1890	0.3292	52.49	<0.0001
	Honda CBR600RR	1	0.8368	130.9%	0.0240	0.7897	0.8839	1214.11	<0.0001
	Honda CBR650F	1	0.5137	67.1%	0.0524	0.4110	0.6165	95.98	<0.0001
	Honda CRF300L	1	-1.5982	-79.8%	0.1158	-1.8251	-1.3712	190.54	<0.0001
	Honda CTX1300	1	0.3075	36.0%	0.0747	0.1611	0.4539	16.94	<0.0001
	Honda CTX700	1	-0.0087	-0.9%	0.0574	-0.1212	0.1039	0.02	0.8802
	Honda CTX700N	1	-0.1175	-11.1%	0.0549	-0.2251	-0.0099	4.58	0.0323
	Honda Forza	1	-0.2147	-19.3%	0.0811	-0.3736	-0.0557	7.01	0.0081
	Honda Fury	1	-0.0277	-2.7%	0.0302	-0.0869	0.0315	0.84	0.3598
	Honda Grom	1	-1.5163	-78.0%	0.0502	-1.6147	-1.4180	913.03	<0.0001
	Honda Interceptor (model years 2002-09)	1	0.3522	42.2%	0.0362	0.2812	0.4233	94.54	<0.0001
	Honda Interceptor (model years 2014-15)	1	0.5454	72.5%	0.0829	0.3829	0.7079	43.27	<0.0001
	Honda NC700X	1	-0.1632	-15.1%	0.0467	-0.2547	-0.0717	12.22	0.0005
	Honda PCX150	1	-0.4786	-38.0%	0.0976	-0.6700	-0.2872	24.02	<0.0001
	Honda Rebel 300	1	-0.2475	-21.9%	0.0453	-0.3362	-0.1587	29.86	<0.0001
	Honda Rebel 500	1	-0.2814	-24.5%	0.0397	-0.3591	-0.2036	50.33	<0.0001
	Honda Reflex	1	0.0781	8.1%	0.0466	-0.0132	0.1693	2.81	0.0935
	Honda Silver Wing	1	0.3769	45.8%	0.0376	0.3033	0.4505	100.71	<0.0001
	Honda ST1300	1	0.0171	1.7%	0.0364	-0.0542	0.0884	0.22	0.6389
	Honda Stateline	1	0.2609	29.8%	0.0546	0.1539	0.3679	22.85	<0.0001
	Indian Scout	1	-0.3737	-31.2%	0.0356	-0.4435	-0.3039	110.13	<0.0001
	Indian Scout Sixty	1	-0.3261	-27.8%	0.0516	-0.4273	-0.2249	39.9	<0.0001
	Kawasaki Concours 14	1	0.4801	61.6%	0.0332	0.4151	0.5451	209.61	<0.0001
	Kawasaki KLR 650	1	-0.6019	-45.2%	0.0748	-0.7484	-0.4553	64.77	<0.0001
	Kawasaki KLX 230	1	-1.6042	-79.9%	0.1816	-1.9601	-1.2483	78.06	<0.0001
	Kawasaki Ninja 1000	1	0.5810	78.8%	0.0661	0.4515	0.7105	77.28	<0.0001
	Kawasaki Ninja 300	1	0.2343	26.4%	0.0272	0.1810	0.2876	74.23	<0.0001
	Kawasaki Ninja 650	1	0.5247	69.0%	0.0313	0.4634	0.5861	280.85	<0.0001
	Kawasaki Ninja ZX-10R	1	0.9273	152.8%	0.0405	0.8480	1.0066	525.18	<0.0001

Table A2: Illustrative regression results — motorcycle collision ABS									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	*p*-value
	Kawasaki Ninja ZX-14R	1	0.6923	99.8%	0.0518	0.5909	0.7937	178.94	<0.0001
	Kawasaki Ninja ZX-6R	1	0.8985	145.6%	0.0282	0.8432	0.9538	1013.91	<0.0001
	Kawasaki Versys-X 300	1	-0.7535	-52.9%	0.1207	-0.9900	-0.5169	38.96	<0.0001
	Kawasaki Vulcan 1700	1	-0.0035	-0.3%	0.0502	-0.1018	0.0948	0	0.9443
	Kawasaki Vulcan S	1	-0.2895	-25.1%	0.0381	-0.3641	-0.2149	57.89	<0.0001
	Suzuki Bandit 1250	1	0.2982	34.7%	0.0646	0.1717	0.4248	21.34	<0.0001
	Suzuki Burgman 400	1	0.2819	32.6%	0.1370	0.0135	0.5504	4.24	0.0396
	Suzuki Burgman 650	1	0.2302	25.9%	0.0356	0.1604	0.2999	41.82	<0.0001
	Suzuki SV650	1	0.2724	31.3%	0.0328	0.2081	0.3366	68.95	<0.0001
	Suzuki V-Strom 650	1	-0.2513	-22.2%	0.0504	-0.3501	-0.1524	24.83	<0.0001
	Triumph Speed Triple	1	0.2610	29.8%	0.0911	0.0824	0.4396	8.2	0.0042
	Triumph Sprint ST	1	0.4899	63.2%	0.0601	0.3721	0.6078	66.42	<0.0001
	Triumph Thunderbird	1	-0.1904	-17.3%	0.0889	-0.3647	-0.0161	4.58	0.0323
	Triumph Tiger	1	-0.0031	-0.3%	0.0757	-0.1515	0.1452	0	0.9671
	Triumph Tiger 800	1	-0.3434	-29.1%	0.0879	-0.5156	-0.1713	15.28	<0.0001
	Victory Cross Country	1	0.0441	4.5%	0.0484	-0.0508	0.1390	0.83	0.3621
	Victory Vision	1	0.1686	18.4%	0.0763	0.0191	0.3182	4.88	0.0271
	Yamaha FJR1300	1	0.2335	26.3%	0.0429	0.1493	0.3176	29.56	<0.0001
	Yamaha FZ-07	1	-0.0024	-0.2%	0.0648	-0.1294	0.1247	0	0.9710
	Yamaha YZF-R3	1	0.0557	5.7%	0.0439	-0.0304	0.1418	1.61	0.2050
	Honda Gold Wing	0	0	0	0	0	0		
Vehicle age		1	-0.1033	-9.8%	0.0019	-0.1071	-0.0995	2815.47	<0.0001
Rated driver age group	Unknown	1	0.2354	26.5%	0.0283	0.18	0.2908	69.39	<0.0001
	14-24	1	1.1274	208.8%	0.0176	1.093	1.1619	4115.76	<0.0001
	25-39	1	0.4513	57.0%	0.0126	0.4266	0.476	1280.28	<0.0001
	65+	1	0.0201	2.0%	0.0167	-0.0127	0.0528	1.44	0.2305
	40-64	0	0	0	0	0	0		
Rated driver gender	Female	1	-0.156	-14.4%	0.0165	-0.1883	-0.1236	89.26	<0.0001
	Unknown	1	-0.0080	-0.8%	0.0377	-0.0818	0.0659	0.04	0.8329
	Male	0	0	0	0	0	0		
Rated driver marital status	Single	1	0.2029	22.5%	0.0111	0.1811	0.2246	332.99	<0.0001
	Unknown	1	0.0266	2.7%	0.0371	-0.0461	0.0993	0.52	0.4727
	Married	0	0	0	0	0	0	.	.
Rated driver risk	Non-standard	1	0.1209	12.9%	0.0151	0.0914	0.1504	64.57	<0.0001
	Standard	0	0	0	0	0	0		
Registered vehicle density	0-100	1	0.4024	49.5%	0.0223	0.3587	0.4461	326.21	<0.0001
	101-250	1	0.4032	49.7%	0.0162	0.3714	0.435	617.78	<0.0001
	250-500	1	0.2318	26.1%	0.0129	0.2064	0.2571	321.18	<0.0001
	501+	0	0	0	0	0	0		
Deductible	0-99	1	-0.3076	-26.5%	0.014	-0.3351	-0.2802	481.74	<0.0001
	100-499	1	-0.1837	-16.8%	0.0108	-0.2049	-0.1625	288.85	<0.0001
	500+	0	0	0	0	0	0		
State	Alaska	1	-0.5428	-41.9%	0.1008	-0.7405	-0.3452	28.97	<0.0001
	Alabama	1	-0.3523	-29.7%	0.0386	-0.4279	-0.2767	83.44	<0.0001

Table A2: Illustrative regression results — motorcycle collision ABS									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	*p*-value
	Arkansas	1	-0.2364	-21.1%	0.0457	-0.3260	-0.1468	26.73	<0.0001
	Arizona	1	-0.0882	-8.4%	0.0294	-0.1458	-0.0305	8.99	0.0027
	Colorado	1	-0.4723	-37.6%	0.0305	-0.5321	-0.4124	239.34	<0.0001
	Connecticut	1	-0.6211	-46.3%	0.0554	-0.7297	-0.5125	125.55	<0.0001
	District of Columbia	1	0.1611	17.5%	0.1044	-0.0436	0.3657	2.38	0.1229
	Delaware	1	-0.4710	-37.6%	0.0931	-0.6535	-0.2884	25.57	<0.0001
	Florida	1	-0.3973	-32.8%	0.0220	-0.4404	-0.3542	326.41	<0.0001
	Georgia	1	-0.3294	-28.1%	0.0274	-0.3830	-0.2757	144.93	<0.0001
	Hawaii	1	-0.4505	-36.3%	0.0564	-0.5612	-0.3399	63.71	<0.0001
	Iowa	1	-0.7984	-55.0%	0.0490	-0.8944	-0.7024	265.74	<0.0001
	Idaho	1	-0.5207	-40.6%	0.0637	-0.6455	-0.3959	66.88	<0.0001
	Illinois	1	-0.5537	-42.5%	0.0264	-0.6054	-0.5021	441.34	<0.0001
	Indiana	1	-0.6621	-48.4%	0.0372	-0.7351	-0.5891	316.02	<0.0001
	Kansas	1	-0.5382	-41.6%	0.0455	-0.6273	-0.4491	140.12	<0.0001
	Kentucky	1	-0.4732	-37.7%	0.0475	-0.5663	-0.3802	99.31	<0.0001
	Louisiana	1	-0.2372	-21.1%	0.0399	-0.3154	-0.1589	35.29	<0.0001
	Massachusetts	1	-0.4139	-33.9%	0.0379	-0.4881	-0.3398	119.59	<0.0001
	Maryland	1	-0.4495	-36.2%	0.0346	-0.5173	-0.3817	168.81	<0.0001
	Maine	1	-0.7165	-51.2%	0.0874	-0.8877	-0.5453	67.27	<0.0001
	Michigan	1	-0.3596	-30.2%	0.0353	-0.4287	-0.2905	104.05	<0.0001
	Minnesota	1	-0.7836	-54.3%	0.0350	-0.8522	-0.7150	501.20	<0.0001
	Missouri	1	-0.5097	-39.9%	0.0332	-0.5749	-0.4446	235.19	<0.0001
	Mississippi	1	-0.2588	-22.8%	0.0556	-0.3678	-0.1498	21.66	<0.0001
	Montana	1	-0.6879	-49.7%	0.1137	-0.9109	-0.4650	36.58	<0.0001
	North Carolina	1	-0.4687	-37.4%	0.0312	-0.5300	-0.4075	225.23	<0.0001
	North Dakota	1	-0.7808	-54.2%	0.0981	-0.9730	-0.5886	63.39	<0.0001
	Nebraska	1	-0.6156	-46.0%	0.0555	-0.7244	-0.5069	123.14	<0.0001
	New Hampshire	1	-0.5377	-41.6%	0.0628	-0.6609	-0.4146	73.25	<0.0001
	New Jersey	1	-0.5942	-44.8%	0.0395	-0.6715	-0.5168	226.49	<0.0001
	New Mexico	1	-0.3702	-30.9%	0.0513	-0.4707	-0.2697	52.16	<0.0001
	Nevada	1	-0.2179	-19.6%	0.0445	-0.3052	-0.1306	23.94	<0.0001
	New York	1	-0.2726	-23.9%	0.0264	-0.3243	-0.2210	106.96	<0.0001
	Ohio	1	-0.7786	-54.1%	0.0286	-0.8347	-0.7225	739.80	<0.0001
	Oklahoma	1	-0.4875	-38.6%	0.0389	-0.5638	-0.4113	156.94	<0.0001
	Oregon	1	-0.4637	-37.1%	0.0379	-0.5380	-0.3895	149.96	<0.0001
	Pennsylvania	1	-0.5212	-40.6%	0.0260	-0.5722	-0.4703	402.12	<0.0001
	Rhode Island	1	-0.6367	-47.1%	0.1353	-0.9020	-0.3715	22.14	<0.0001
	South Carolina	1	-0.3989	-32.9%	0.0421	-0.4815	-0.3164	89.67	<0.0001
	South Dakota	1	-0.7557	-53.0%	0.0879	-0.9280	-0.5834	73.92	<0.0001
	Tennessee	1	-0.4093	-33.6%	0.0302	-0.4684	-0.3502	184.21	<0.0001
	Texas	1	-0.1891	-17.2%	0.0195	-0.2274	-0.1508	93.66	<0.0001
	Utah	1	-0.5661	-43.2%	0.0435	-0.6514	-0.4809	169.32	<0.0001
	Virginia	1	-0.4823	-38.3%	0.0287	-0.5386	-0.4260	281.92	<0.0001
	Vermont	1	-0.6188	-46.1%	0.1051	-0.8248	-0.4127	34.63	<0.0001
	Washington	1	-0.5629	-43.0%	0.0331	-0.6278	-0.4981	289.43	<0.0001

Table A2: Illustrative regression results — motorcycle collision ABS									
Parameter		Degrees of freedom	Estimate	Effect	Standard error	Wald 95% confidence limits		Chi-square	*p*-value
	Wisconsin	1	-0.7978	-55.0%	0.0348	-0.8661	-0.7295	524.19	<0.0001
	West Virginia	1	-0.8773	-58.4%	0.0688	-1.0121	-0.7424	162.62	<0.0001
	Wyoming	1	-0.7531	-52.9%	0.1096	-0.9680	-0.5382	47.18	<0.0001
	California	0	0	0	0	0	0		
Calendar year	2001	1	-3.8896	-98.0%	38.7643	-79.8663	72.0871	0.01	0.9201
	2002	1	-0.5746	-43.7%	0.4093	-1.3769	0.2276	1.97	0.1604
	2003	1	-0.7419	-52.4%	0.2020	-1.1378	-0.3461	13.49	0.0002
	2004	1	-0.2285	-20.4%	0.1043	-0.4328	-0.0241	4.80	0.0284
	2005	1	-0.1595	-14.7%	0.0736	-0.3038	-0.0152	4.70	0.0302
	2006	1	-0.1735	-15.9%	0.0561	-0.2834	-0.0636	9.57	0.0020
	2007	1	-0.0204	-2.0%	0.0409	-0.1006	0.0599	0.25	0.6186
	2009	1	-0.1424	-13.3%	0.0364	-0.2136	-0.0711	15.32	<0.0001
	2010	1	-0.0422	-4.1%	0.0350	-0.1107	0.0264	1.45	0.2282
	2011	1	-0.0523	-5.1%	0.0352	-0.1214	0.0167	2.21	0.1374
	2012	1	-0.0322	-3.2%	0.0352	-0.1012	0.0368	0.84	0.3604
	2013	1	0.0239	2.4%	0.0343	-0.0434	0.0912	0.49	0.4856
	2014	1	0.0437	4.5%	0.0340	-0.0229	0.1104	1.66	0.1980
	2015	1	0.1493	16.1%	0.0338	0.0831	0.2155	19.52	<0.0001
	2016	1	0.1100	11.6%	0.0346	0.0423	0.1778	10.13	0.0015
	2017	1	0.0350	3.6%	0.0354	-0.0344	0.1044	0.98	0.3227
	2018	1	0.0277	2.8%	0.0362	-0.0431	0.0986	0.59	0.4430
	2019	1	0.0476	4.9%	0.0368	-0.0246	0.1199	1.67	0.1959
	2020	1	-0.0410	-4.0%	0.0379	-0.1153	0.0334	1.16	0.2805
	2021	1	0.0366	3.7%	0.0384	-0.0387	0.1120	0.91	0.3404
	2022	1	0.1335	14.3%	0.0386	0.0578	0.2093	11.95	0.0005
	2023	1	0.0787	8.2%	0.0396	0.0010	0.1564	3.94	0.0472
	2024	1	0.0359	3.7%	0.0407	-0.0439	0.1157	0.78	0.3784
	2008	0	0	0	0	0	0		

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